Reserve

The Agricultural, Scientific, and Economic Basis for Low-Cost Protein Foods 1/

Oct 9, 1967
MIT Single-Cell..Conf.

by Aaron M. Altschul 2/

Introduction

The previous speakers presented evidence of widespread malnutrition, particularly protein malnutrition, on the basis of direct observation. Moreover, it has been made clear that the consequences of such malnutrition are far-reaching: death is only one consequence; another is complete national failure to achieve economic growth because of the impaired physical and mental productivity of the population.

You have also heard evidence of severe inability to provide sufficient calories; the developing countries which were once exporters of grain are now the major importers of grain, and this situation will continue for the foreseeable future.

It is my intention to describe what we are doing now to meet protein needs in ways which do not drain the world's limited calorie supplies; to describe the role of the market place in determining the potential of new protein foods; and to state tentative goals of our efforts. I will examine the inter-relationship of calories to proteins and try to derive therefrom an idea of the role of non-calorie, non-agricultural resources in making the most of our existing calorie resources. And finally, because this is a meeting on Single-Cell Protein, I

1/ For presentation at the International Conference on Single-Cell Protein, MIT, October 9, 1967.

2/ Special Assistant for International Nutrition Improvement, International Agricultural Development Service, U. S. Department of Agriculture. The author expresses appreciation to James C. Cason for assistance in preparing this manuscript.

should comment on factors which may affect future demand for single cell protein.

The program which I shall describe has two aspects: the first, immediate, perhaps temporary, is an effort to reach the poorest people. This calls for fortification of cereals to increase the impact of their protein content.

The second calls for long-range, permanent development of new protein foods. This second program, which may require in its early stages some modicum of government support, is primarily market-oriented. The new food products must succeed in the market place as viable foods. This is true regardless of the country, its politics, or its economic system; no new food can succeed unless it is willingly supported by the population who must spend from its own resources.

Fortification

A. General Discussion

The major source of protein in the world for human food is the cereals. Cereals contribute over 40 million tons of protein annually to humans out of a total of about 82 million tons presently available. This compares to approximately 25 million tons of protein supplied by animals. Although cereals are the major source of protein, the protein from cereals is not as suitable for human food as is the protein from animal sources. The pattern of amino acid composition is inadequate in cereals. Unless the deficient amino acids (protein components) are furnished by other foods eaten together with the cereals, some of the protein in the cereals will be wasted. Hence, those who eat primarily cereals are in danger of not realizing the full protein potential of their food.

The only way quickly to improve the protein quality of a people's food is to build upon current food habits as the basis for improving their diet. Fortification

of cereals in those countries where the majority of the protein comes from cereals is the simplest and quickest way into the improved diet; no changes in social customs are required. There are two general ways of fortifying cereals to improve protein: the first is to add the deficient amino acids, the second is to add protein concentrates.

Supplementation with amino acids does not increase the protein content of the cereals but does improve the quality. In many societies children are fed adult diets shortly after weaning. Improving protein of cereals by supplementation with amino acids can often spell the difference between protein adequacy or inadequacy. Obviously, for cereals of higher protein content, the effectiveness is greater, but there is considerable opinion that fortification can be significantly beneficial even for rice.

The whole notion of using amino acids as the means of improving immediately the protein quality of national diets arises from rather recent developments in producing amino acids at lower costs. DL-methionine and L-lysine are now available at close to $1.00 a pound. The other two amino acids which can contribute to upgrading the quality of cereal proteins, tryptophan and threonine, are available, but at higher costs. Table I gives the estimates provided by Dr. E.E. Howe of the cost of fortification of various cereals with lysine.

Tables II and III estimate the cost of fortification of wheat with lysine, corn with lysine and tryptophan, and rice with lysine and threonine, both in absolute terms and in percentage of the cost of the cereals themselves.

Table I.

Lysine supplementation of cereal grains*

Cereal	Nutritive value 1/ Original	After Supplementation	Lysine 2/ added %	Estimated Cost 3/
Whole wheat	1.3	1.7	0.1	$0.28
Wheat flour	0.7	1.6	0.25	0.70
Rice	1.5	1.8 - 2.2	0.05	0.14
Corn	1.5	1.9 - 2.2	0.1	0.28
Millet	0.7	2.1	0.3	0.84
Sorghum	0.7	2.2	0.3	0.84
Casein		2.5		

1/ In terms of protein efficiency ratio (PER) determined on rats

2/ Added as L-lysine HCl

3/ Cost of supplementing cereal per child per year based on assumed cost of $1.00 per pound.

* From E.E. Howe in Proc. Conf. the Technology of Food Supply, Oct. 25, 1966 (Dairy and Food Industries Supply Association, Washington, D.C. 1967) p. 60

Table II.

Absolute Costs of Cereal Fortification with Amino Acids

Cereal	Cost per metric ton
Wheat flour + 0.2% lysine	$ 4.40
Whole wheat + 0.1% lysine	$ 2.20
Maize + 0.1% lysine	$ 2.20
Milled rice + 0.05% lysine	$ 1.10
Maize + 0.3% lysine + 0.07% DL-tryptophan	$13.61
Milled rice + 0.2% lysine + 0.2% DL-threonine	$34.47

Assumed costs:

L-lysine $1.00 pound
DL-threonine $7.50 pound
DL-tryptophan $4.54 pound

Table III.

Relative Costs of Cereal Fortification with Amino Acids
(Expressed as a percentage of cereal wholesale prices in 1964)

Cereal	India	UAR	Mexico
1. Wheat flour + lysine	5.2%		3.8%
2. Whole wheat + lysine	1.8%		2.1%
3. Maize + lysine	2.2%	4.4%	2.8%
4. Milled rice + lysine	0.8%	1.5%	
5. Maize + lysine + tryptophan	13.3%	21.2%	17.4%
6. Milled rice + lysine + threonine	24.4%	46.5%	

Calculations

A. Assumed amino acid cost: L-lysine $1.00 pound; DL-tryptophan $4.54 pound; DL-threonine $7.50 pound.

B. Amino acid fortification level:

1. 0.2% lysine
2. 0.1% lysine
3. 0.1% lysine
4. 0.05% lysine
5. 0.3% lysine + 0.07% DL-tryptophan
6. 0.2% lysine + 0.2% DL-threonine

It is quite clear that partial fortification of wheat or rice with lysine is now economically feasible. Complete fortification of corn can now be considered even at a cost of $4.50 per pound of DL-tryptophan; the situation will improve as the cost of tryptophan is reduced. Total fortification of rice, which would involve threonine as well, could possibly be justified at L-threonine prices of $2 - $4 per pound.

Not only are the amino acids available, but a technology is evolving for the fortification process. There is no question that wheat or corn flour can easily be fortified by the same procedures used in fortification with vitamins. The fortification of formed grains is not quite so simple. However, Dr. Frederick Senti (International Agricultural Development Newsletter, May 1967) reports that lysine can be impregnated into wheat berries up to a level of 10%; this might be the way to fortify wheat grains being shipped into a country. Moreover, there is evidence that amino acids can be encapsulated in such a way that they cannot be dissolved in hot water. Therefore, means are available to produce 'formed' rice grains for the fortification of this grain.

There is an alternative to fortification with amino acids: add soy or other oilseed protein or fish protein concentrate (FPC) to the flours. This has the advantage of <u>increasing</u> protein content while adding amino acids to improve the quality of existing protein. Wheat flour has been fortified with soy protein in Israel. Dr. George G. Graham (personal communication) conducted successful experiments on the fortification of wheat flour with fish protein concentrate.

Actually, there exists a three component system: the cereal grains, amino acids, and protein concentrates. For every locality there exists a mixture of these three (or of two of the three) most suitable and economic. Fortification

should also include the addition of necessary vitamins as well as the amino acids or protein concentrates.

We should comment on the relationship of fortification to efforts toward breeding better quality cereal proteins, such as the development of so-called high lysine corn or of breeding for higher protein content in other grains. Breeding has the advantage that the improvement is permanent and does not require daily attention. However, new varieties will only be grown if total yield of the calorie sources are maintained. Since there is a shortage of calories in developing countries and since the farmers' income depends on yield per acre, yield will be the overriding factor in determine the economic success of a new variety. Where quality can be improved at no expense to yield, introduction of new varieties will be facilitated; where fortification of a cereal has been practiced successfully, this practice can be withdrawn or altered, as necessary, when the prevailing calorie source has changed to one of higher quality protein.

B. What We Have Done About Fortification

Having convinced ourselves of the unique aspects of this approach in terms of the immediate, urgent need for protein improvement, we raised the subject among a number of important scientific groups. Support was received from the Food and Nutrition Board of the National Academy of Sciences which recommended that a large scale demonstration program be undertaken. Similar support came from the President's Science Advisory Committee on the World Food Problem, from the Protein Advisory Group of the United Nations, from the Special Protein Panel of the United Nations, and from the International Symposium on Oilseeds held in June 1967 at Mysore, India.

It is clear that demonstrations on a large scale are needed to determine the feasibility of large scale fortification, to determine the logistics of such an operation, and to see whether the fortification indeed reaches the consumer. In a larger sense, there is need for public health demonstrations of what is accomplished by fortification. This is a general problem encountered in fortification and improvement in public health. It is very difficult to measure the economic benefits in a short time; there is a body of opinion that suggests that the benefits cannot be measured at all because of the many complications. Nevertheless, a series of tests need be conducted to determine the time needed to measure benefits to justify the cost of fortification, small as it might be compared to other costs.

With this in mind, we have approached a number of governments to determine whether they might be interested (1) in setting up such demonstrations and, (2) in going ahead with fortification when they feel that the problems have been worked out. Such discussions have been held with authorities and scientists in India, Tunisia and Peru. They are being contemplated for other Latin American countries and for several countries in Asia, with emphasis on rice fortification in the latter

The major amino acid producers have been stimulated to reduce the costs of amino acids as quickly as possible and to participate in demonstration experiments whenever feasible. One such demonstration is being discussed for Iran. Discussions have also been held with agencies of the United Nations to obtain their support and active participation in these demonstration experiments, as well as to help bring these ideas to practical fruition.

There are already some consequences from this recent activity; Incaparina, the well-known cottonseed-corn mixture in Central America, is now fortified in

Guatemala with lysine. While Incaparina alone has been proved effective in combatting infant malnutrition, fortified Incaparina has a protein quality equal to that of casein and is thereby more effective from an economic viewpoint. A shipment of 5,500 tons of wheat flour fortified with lysine is on its way to India from a European port as part of a relief shipment. Serious discussions are going on in India on fortification with lysine of the infant food Bal Ahar.

C. Fortification Goals

A comment, perhaps, is in order on having goals in the first place. Many efforts have been made to define the extent of the malnutrition problem in quantitative terms. This has been done in terms of deficiency of animal protein, deficiency of milk protein, or deficiency of total protein. All agree that there is a serious protein deficiency. Another approach might be to set forth certain attainable goals and evaluate what happens when these are met. Goals for fortification might be that all emergency shipments of wheat and corn flour be fortified by 1969; and that all imports of wheat and all wheat products in large urban milling centers in developing countries be fortified by 1970. We would hope that substantial progress be made in the technology of fortification of rice by 1968.

New Protein Foods

A. Recent Developments

New protein foods must be acceptable to the population - as acceptable as conventional protein foods - must be low cost, and must be made primarily from raw materials indigenous to the country or easily imported. The ultimate criterion of the success of such foods is their self-sufficiency in the market place. Such

a criterion highlights the role of the private sector in developing these new foods. The private sector must be more heavily involved in solving the food problems of the developing countries. The need for self-sufficiency of new foods in the market place emphasizes the unique role of the private sector.

An experimental program was developed by the Agency for International Development aimed specifically at encouraging the development of these new foods. It was felt that food companies would need some help and encouragement to understand the market; to determine the costs and availability of raw materials; in mapping the distribution system; and market-testing prototypes to determine the kinds of new foods that might succeed in a given country. Hence, AID established a high protein food program whereby food companies receive grants to enable them to make these studies and to prepare themselves for an investment decision. The information gained in these studies will be of value to all food companies interested in the same objectives.

Five contracts were signed by mid 1967 with American companies to encourage development of new protein foods. The studies include: a protein beverage for El Salvador; a soy protein beverage, fortified corn foods, and soy foods for Brazil; and protein foods from high protein wheat fractions for Tunisia. This year, numerous contracts are being negotiated for continuation of this program. These include investigations on cottonseed protein concentrate for human consumption textured soy products, sterile protein beverages, coconut protein foods for humans, fortified rice grains, and baby foods. This is an experimental program for three years at total annual cost of about $400,000 per year. Preliminary results from the activities that have been generated show promising progress and an enthusiastic response on the part of the worldwide food industry.

There are certain characteristics of these new foods worth mentioning. It is understood that these foods will not immediately reach the lowest economic strata of any given population. The first attempt at reaching such people would be through fortification of cereals. Nevertheless, these new foods will make it possible for a wider segment of any society to enjoy the nutritive value and the aesthetic satisfaction of foods which approach the more expensive protein foods.

It should be expected that these foods will be fortified with the requisite amino acids, as necessary, to achieve the highest protein quality. One would also expect that textured foods, which might be more expensive than others would, nevertheless, be explored to determine what can be expected from them as part of a total strategy.

B. Worldwide Goals for New Foods

A tentative goal of 1 billion additional cups of protein beverage per day by 1970 might be appropriate. This is equivalent to one million tons of additional protein per year, about ten percent of the amount of protein presently supplied by milk. We emphasize beverages because they may be the easiest food to produce and the most acceptable. Moreover, this is a food most useful to infants. However, any other foods that make a large-scale contribution to protein supply certainly would be considered as part of this goal.

Financing These Programs

Fortification costs must be absorbed by the consumers out of savings gained by reducing the requirement for more expensive foods. In those areas where governments are subsidizing part or all of the costs of basic cereal foods,

fortified cereals should be supplied, instead. All of the cereal products on a national market could be fortified by law, to make this an effective procedure.

The new protein foods must find their place in the market. They must supply evidence that they are viable commercial entities in order to deserve any additional support.

These new foods, however, can be considered a third generation of foods suitable for special purposes. The first of these special purpose foods was a non-fat dry milk. Following World War II when there was a great need for protein supplies, non-fat dry skim milk was distributed by UNICEF and made an enormous impact on mothers and children. The milk for this program was supplied largely from surplus stocks of the United States and Canada.

When the supply of non-fat dry skim milk became short, a second generation of new foods was developed. These were the low-cost, primarily or totally, vegetable protein mixtures that were shown to be the nutritional equals of animal foods.

Included in this group was the pioneer Incaparina, Pronutro of South Africa, CSM (corn, soy, milk), Bal Ahar in India, and others. All of these have been distributed in special feeding programs in clinics and schools, or such role is projected for them. Incaparina and Pronutro are being sold commercially in several countries.

Now we have come to the third generation. These are market-oriented, new foods developed primarily for the commercial marketplace but nevertheless nutritious. We can, however, conceive that these new foods will also play a role in special feeding, such as in school lunch programs, or for infants in clinics, or for special feedings for populations that need more protein. When this new food

development materializes, we will have come a full circle from the original utilization of non-fat dry skim milk, itself a material sold primarily in the commercial marketplace. The line between the second and third generation foods is not yet clear; some of the second generation foods are evolving into commercially viable products.

Whatever their origin, eventually it should be expected that all foods in special relief programs will be taken from those acknowledged as commercially viable products.

Economic Basis for Fortification and for New Protein Foods

It is generally recognized that the consumption of animal protein is related to the affluence of a society. This is shown in Figure 1 (taken from Brown) which shows the relationship between per capita animal protein consumption and per capita income. Of more relevance to us here is the cost of animal protein food in terms of grain production. This has been illustrated by Brown in terms of a "grain ladder" shown in Figure 2.

Even though the maximum direct human consumption of cereal grains never exceeds 400 pounds per person per year, many countries exceed this in terms of total grain consumption. The additional grain is fed to animals which provide both protein and calories.

This is shown in a different way in the following two figures: Figure 3 summarizes the relationship between per capita consumption of animal protein and percentage of available grain fed to animals. Over the world, consumption of animal protein ranges from two to 52 pounds per capita per year; the percentage of total grain supplies fed to animals varies from less than one up to 80 percent.

This variability is a measure of many things, including income and quality of diet.

Figure 4, a more detailed exposition of the data in Figure 3, illustrates the role of fish as a source of protein. Two values of animal protein consumption are given for Japan, Portugal, Israel, Norway, and Denmark: one (the higher level) is for total, the other is for the animal protein available from livestock alone. These countries are able to maintain a much higher animal protein consumption by using fish protein to good advantage.

A second interesting point in Figure 4 is the role of good grazing conditions: this puts Argentina, Uruguay, Australia, and New Zealand in a special class.

Figure I.

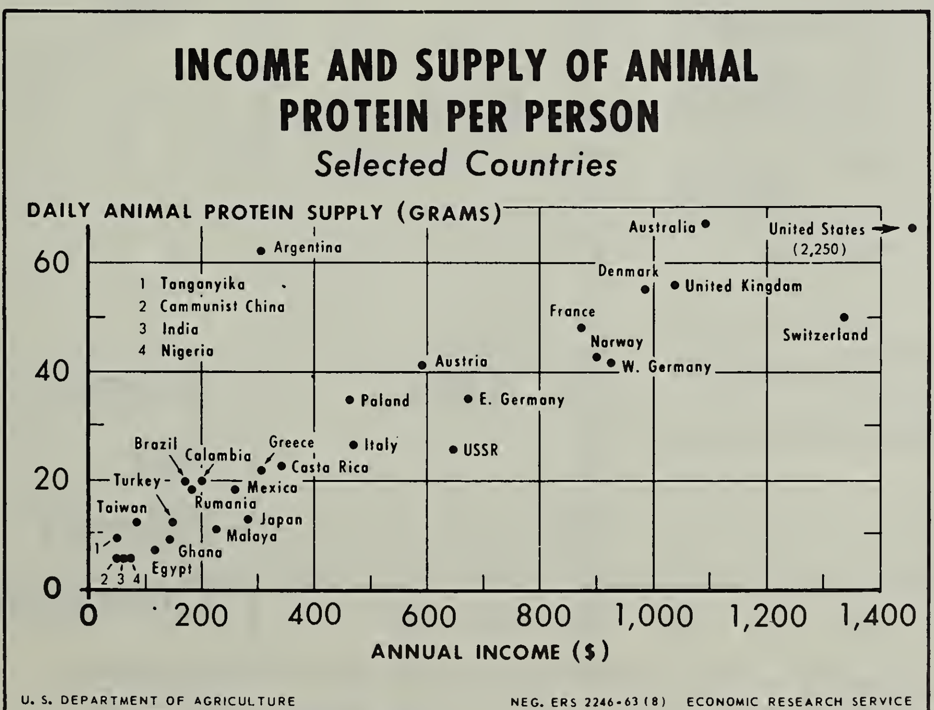
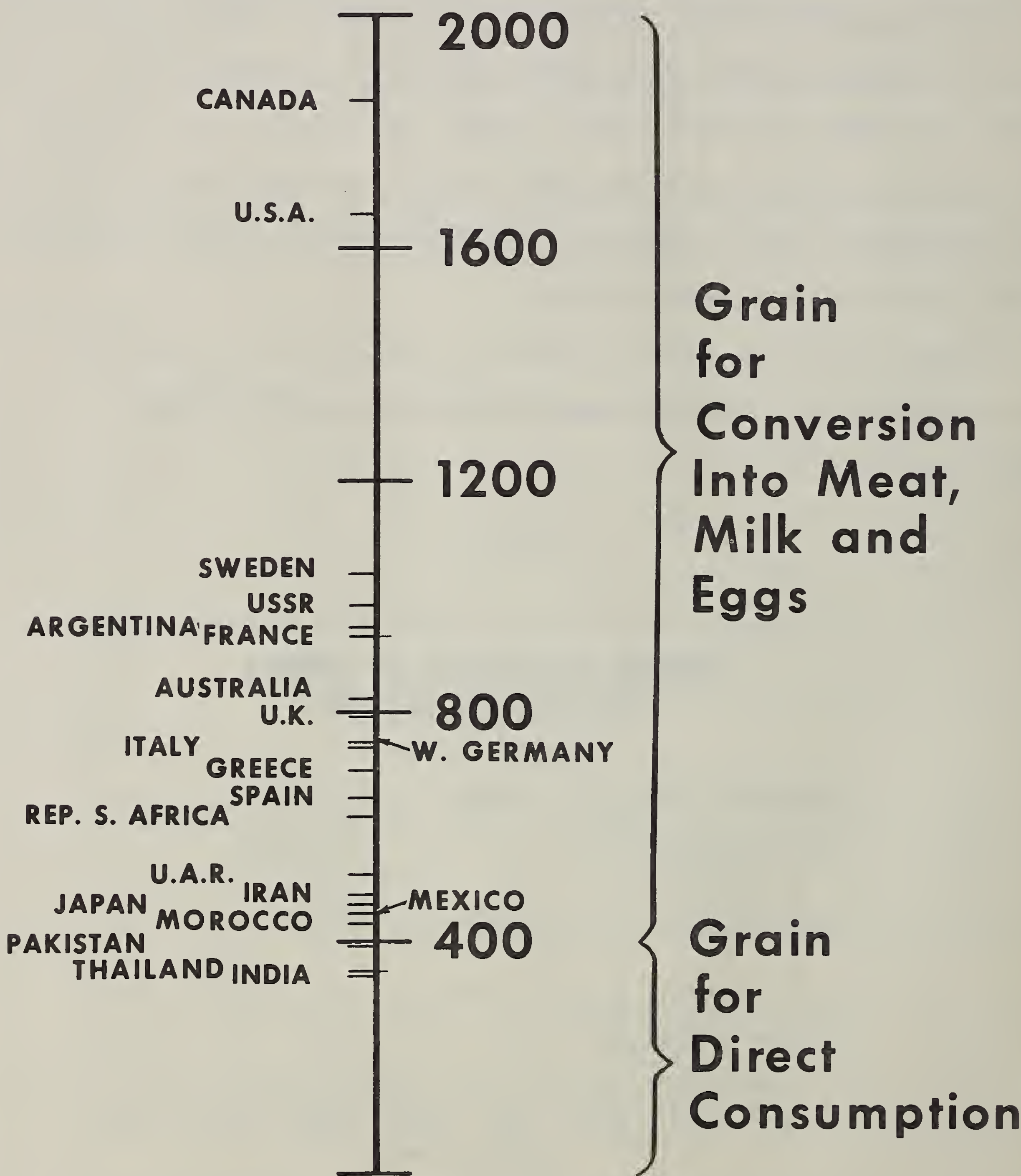


Figure 2.

GRAIN REQUIREMENTS LADDER

(Pounds of grain used per person per year)*

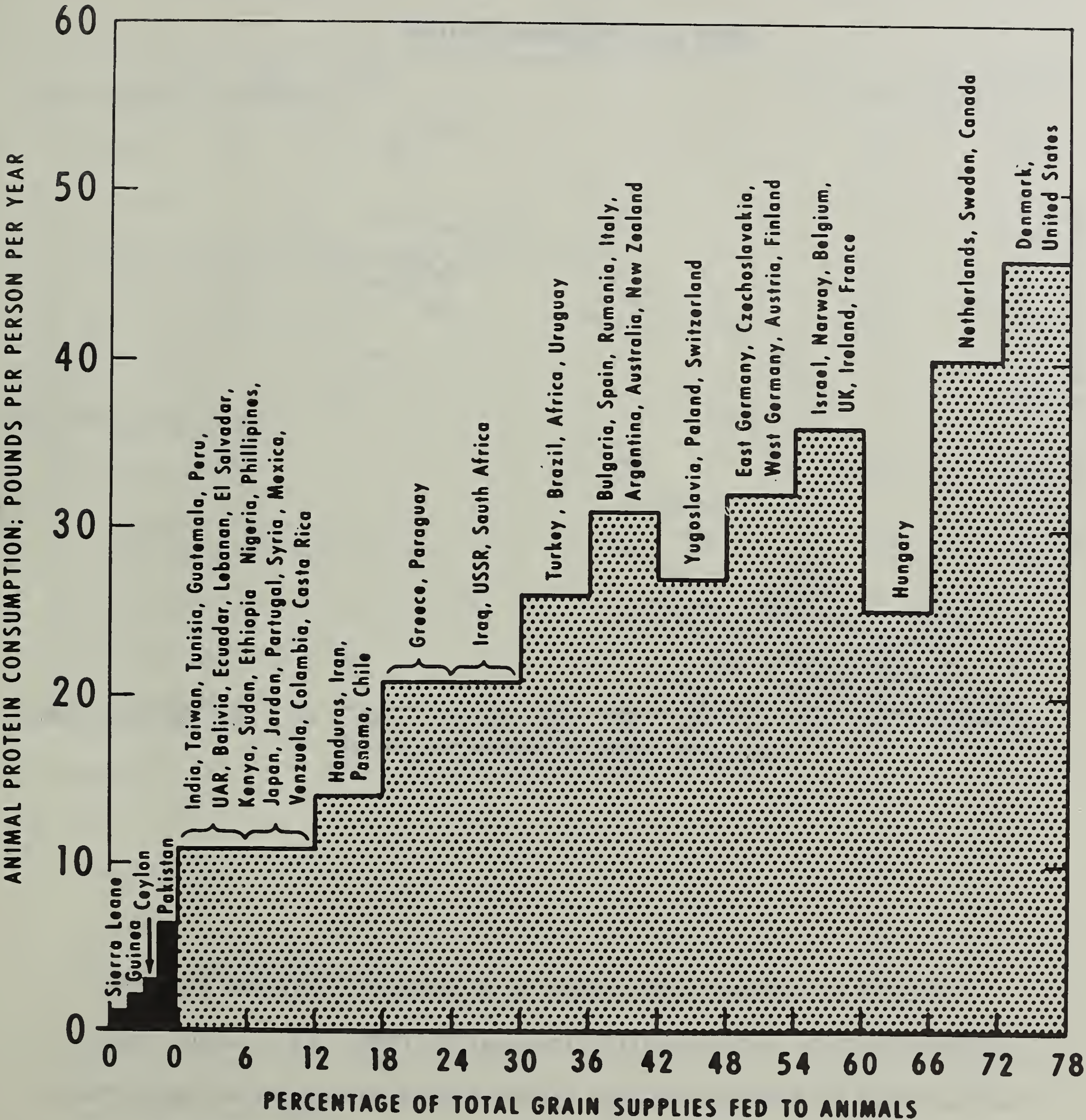


**INCLUDES GRAIN USED FOR FOOD, FEED, SEED AND INDUSTRIAL PURPOSES.*

U.S. DEPARTMENT OF AGRICULTURE BN 28407

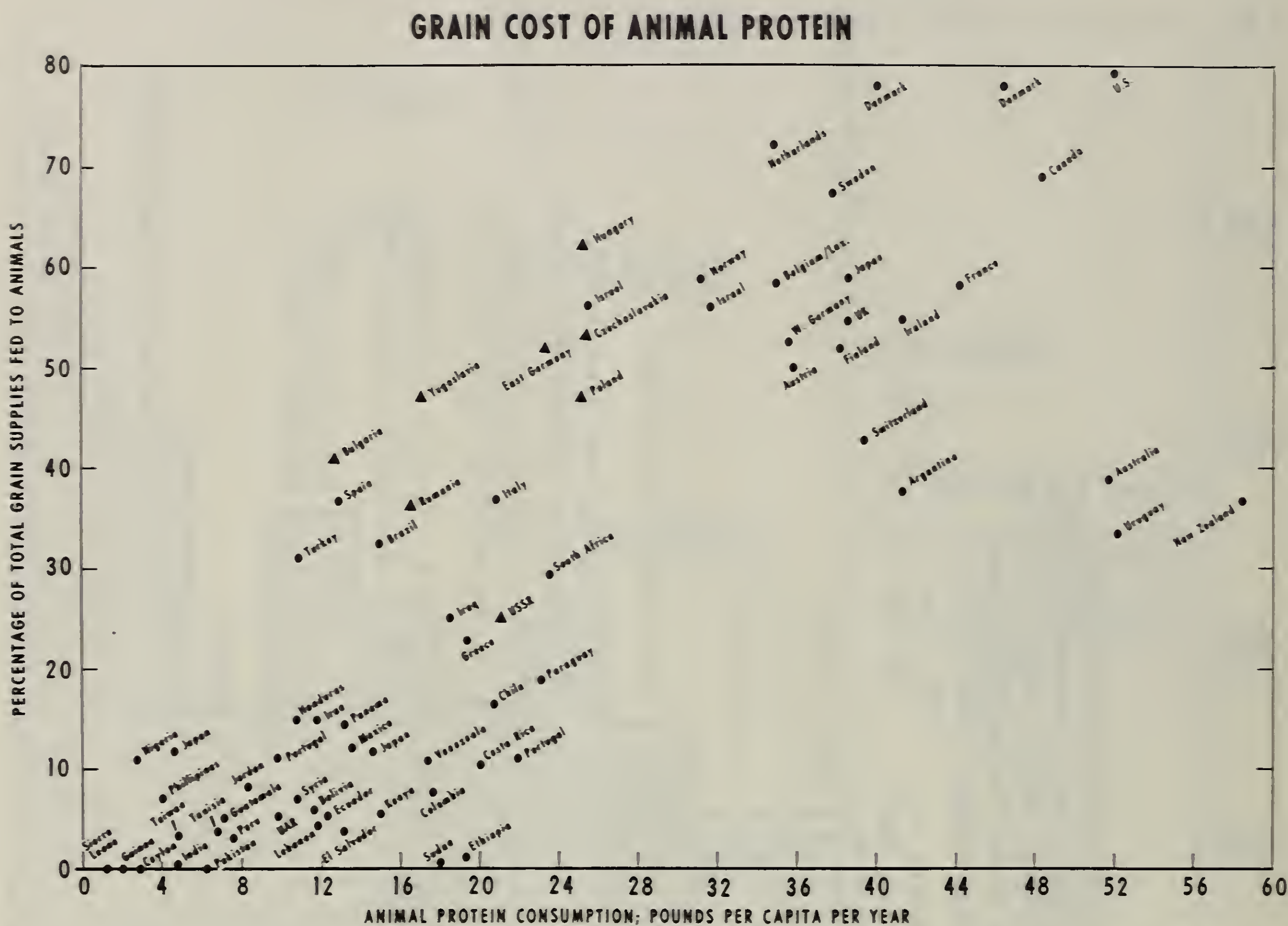
Figure 3.

GRAIN COST OF ANIMAL PROTEIN



BN 30834

Figure 4.



BN 30835

This is the picture now; there is no reason to believe that the situation will be substantially different by 1980. In a recent issue on the World Food Situation, the United States Department of Agriculture predicts that given normal commercial and economic conditions, the per capita consumption of grains by 1980 will be as shown in Table IV.

Table IV.

Estimated Per Capita Consumption of Cereal Grains in 1980*

Less Developed Countries	Kg. per capita
India	186
Pakistan	194
Other Less Developed Countries (excluding grain exporters)	190
Net grain exporters	255
Developed Countries**	
United States	856
Developed exporters (excluding United States)	599
Other developed Western world	610
Eastern Europe + USSR	590
Communist Asia	195
Average:	
Developed	658
World	299
Less Developed Countries	195

* Modified from: World Food Situation, USDA/FAER No. 35, Table 10. (Based on: Rapid improvement in production - more emphasis on agriculture in less developed countries)

** The estimated per capita consumption is not shown in the original Table 10; these figures are calculated from data in this publication.

Yearly per capita consumption of grains in the less developed countries will average-at best-189 kilograms, as against 658 kilograms for the developed countries; the world average is estimated at 299.

The amount of grain estimated as available for the less developed countries is barely sufficient to support the caloric requirements and not adequate to support a substantial animal protein economy. It is obvious, therefore, that the developing countries, to improve the quality of their food, both nutritionally and aesthetically, will require non-grain inputs. As we originally pointed out, this can come about by fortifying cereal grains and by developing new foods from oilseed proteins and other protein concentrates such as fish and single cell protein. The obvious exception is the potential, wherever it exists, for improved grazing. Here would be a way to improve animal protein availability without requiring grain which is more likely to go directly to the human being.

The successful solution to improving protein quality in any particular instance in a developing country will be that which does the job at the lowest cost. This consideration will determine the relative role of amino acids as against protein concentrates. We can foresee situations where, despite the lower world-wide costs of one approach, another will be tried because of the availability of specific foodstuffs or food additives in the local market. We can envisage this happening where fish protein concentrate is available, for example. In general, oilseeds are a cheaper source of protein for new protein foods than other alternatives. Where oilseeds are available for new foods, other resources will encounter stiff competition. Hence, in any economy dominated by soybeans, or where peanuts or cottonseeds, or even, perhaps, coconuts are available, these other sources of protein might find serious competition. It is the cheapest, thus far, to

produce calories by photosynthesis, and to produce protein as plant protein by photosynthesis.

Some Comments on Single Cell Proteins

It is obvious that the world will require non-agricultural resources to support and improve food quality. The availability of such non-grain and non-agricultural resources increases the total world grain supply since it frees the grain for direct human consumption. Therefore, it is quite clear that single cell protein has its place. But this place is not automatically assured. The proteins from microorganisms must be cheap and competitive with other sources of protein, must be of good nutritive quality, and must be palatable.

But this is only the beginning. It must be possible to fabricate single cell protein into foods that are a commercial success. The market is the ultimate, often fatal, test. My guess is that single cell proteins can be made into nutritious and acceptable foods, but this will take more effort and development.

Many are interested and are following the progress of protein from single cell organisms. But few are waiting with open arms and bated breath. Those of you who are interested in promoting this new source of protein will have to fight your way into the market - but, of course, you know this.

Selected References

Altschul, A. M., ed. Processed Plant Protein Foodstuffs (1958) Academic Press, New York.

Altschul, A. M., Proteins, Their Chemistry and Politics (1964) Basic Books, New York.

Altschul, A. M., Food Proteins: New Sources from Seeds (in Press) Science.

Brown, Lester R., The World Food/Population Problem: An Overview, International Agricultural Development Service, M-2, 1966.

Corn Industries Research Foundation, a division of Corn Refiners Association, Inc., Washington, D.C., Proceedings of the High Lysine Corn Conference June 21-2, 1966.

F.A.O. of the U.N. Protein: at the Heart of the World Food Problem, Rome 1964.

Gould, Robert F., Ed., World Protein Resources, American Chemical Society, Advances in Chemistry Series (A Symposium sponsored by the American Chemical Society, Aaron M. Altschul, Chairman), Washington, D.C. 1966.

International Agricultural Development Newsletter, Strategy for New Protein Supplies, number 31, May, 1967.

National Academy of Sciences - National Research Council, Progress in Meeting Protein Needs of Infants and Pre-school Children, Publication no. 843, Washington, D.C., 1961.

Orr, Elizabeth and Adair, David, The Production of Protein Foods and Concentrates from Oilseeds, Ministry of Overseas Development, Tropical Products Institute 56/62 Gray's Inn Road, London, WC1, Report #G31, June 1967.

United Nations Economic and Social Council, Increasing the Production and Use of Edible Protein, document E 4343, 25 May, 1967.

Selected References

U.S. Department of Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries, Marine Protein Concentrate, Fishery Leaflet 584, Washington, D.C., April, 1966.

United States of America, Interdepartmental Committee on Nutrition for National Development, National Institutes of Health, Bethesda, Maryland, Translations of the Second Far East Symposium on Nutrition, Taipei, Taiwan, China, May 18-25, 1964.

The World Food Problem; A Report of the President's Science Advisory Committee, Vol. I & II, The White House, U.S. Gov't. Printing Office, May 1967.